TECHNICKÁ UNIVERZITA V KOŠICIACH
FAKULTA ELEKTROTECHNIKY A INFORMATIKY

Konferencia UAV 2023

Kód projektu: 313011V422
„Inteligentné operačné a spracovateľské systémy pre UAV“

ISBN 978-80-553-4389-1

2023

Zborník z konferencie UAV 2023

Vydavateľ: Fakulta elektrotechniky a informatiky
Technická univerzita v Košiciach
Letná 9, 040 01 Košice, Slovenská republika

Dátum vydania: máj 2023

Tlač: 50 kusov CD

Jazyk: slovenský, anglický

Strán: 86

Editor: Ing. Miroslav Michalko, PhD.

 ISBN: 978-80-553-4389-1

O konferencii UAV 2023

Projektová konferencia UAV 2023 bola organizovaná na pôde Technickej univerzity v Košiciach, v rámci prezentačných priestorov Univerzitného vedeckého parku TECHNICOM, v dňoch 11. – 12. 5. 2023, v rámci projektu:

Názov projektu:	Inteligentné operačné a spracovateľské systémy pre UAV
Kód projektu:	313011V422
Prijímateľ NFP:	GLOBESY, s.r.o.
Partneri:	Qintec a.s.
	YMS, a.s.
	Technická univerzita v Košiciach (TUKE)
	Žilinská univerzita v Žiline (UNIZA)

(ďalej len „projekt UAV“).

Projekt UAV je spolufinancovaný z prostriedkov Európskeho fondu regionálneho rozvoja v rámci Operačného programu Integrovaná infraštruktúra.

EURÓPSKA ÚNIA
Európske štrukturálne a investičné fondy
OP Integrovaná infraštruktúra 2014 – 2020

Riadiaci orgán:

MINISTERSTVO
DOPRAVY
SLOVENSKEJ REPUBLIKY

V zastúpení na základe splnomocnenia:

VÝSKUMNÁ
AGENTÚRA

Obsah

Experimental design of UAV usage in intralogistics

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***Abstract* — This paper deals with benefits of drone usage in automobile industry. After this analysis, use the gained knowledge and design experiments consisting of analyzed concepts and components to prove ability of successful deployment of designed experiment. Finally perform these experiments as proof of concepts. This work is result of diploma thesis and presents implementation of simple UAV device running within interior using video camera source for orientation with the utilisation of markers.**

***Keywords* — drones, UAVs, intralogistics, markers, GPS**

I. Introduction

UAVs are an important part of a concept called Industry 4.0. This can be understood as the next phase in industrial evolution. Previous industrial changes were referred to as revolutions because they were backed by significant inventions such as mechanization, the turbine engine, the construction of automobiles, and the first computer. The concept of Industry 4.0 does not come with a single invention or scientific discovery but rather with the transformation of already common methods. This transformation includes sensors, machines, and IT systems that are interconnected to increase overall productivity. According to [5], these interconnected systems, also referred to as cyber-physical systems, can interact with each other using standard Internet protocols and analyze data to predict failures, reconfigure themselves, or adapt to change and new requirements.

II. Problematics of indoor UAV localization and controlling

Outdoor UAV navigation has already become a part of modern industry since Industry 4.0 was introduced, revolutionizing surveillance and research as we previously knew it. Drones are now being used for monitoring large areas like parks and forests and then, with the help of artificial intelligence and/or other nine pillars of Industry 4.0 [3], evaluate the collected footage and data. According to [4], we face two main challenges when trying to navigate UAVs indoors.

Firstly, and this is the main problem we are trying to address in our thesis, is the issue of insufficient signal reception indoors, which results in an inability to rely on GPS. Unlike conventional navigation based on GPS / INS, from which we can directly obtain the global position and speed of the object we are monitoring, in the case of indoor navigation, we must obtain this information using sophisticated algorithms based on sensors and other data sources describing the object. It's important to note that even when GPS is available, its accuracy isn't high enough to be used under our testing conditions.

The second problem is that conventional drones are designed to be as light as possible, and thus cannot contain heavy processing units, resulting in limited onboard computing power. This complicates indoor drone localization as the drone is unable to carry out heavier computing tasks like image processing. While this can be resolved with a ground control station, it increases the cost of the solution and adds complexity. There have been published articles about implementing SLAM techniques (Simultaneous Localization and Mapping, a technique which uses GCS where drones create a virtual map in an unknown area or update it in an already known area while simultaneously tracking their location) [8, 9]. However, the majority of these were conducted under almost perfect laboratory conditions (for instance, with optimal signal strength). Such conditions render the solutions impractical or even impossible to implement in real life, as we cannot guarantee certain conditions on which we will later rely when potentially executing tasks in dangerous situations, or where there is a risk of damaging the drone or its surroundings.

III. MARKERS

Fiducials, or more simply "markers," are reference objects placed in the camera's field of view when an image or video frame is captured. They are positioned in the environment and provide easily identifiable visual cues for indoor tracking, robot and drone navigation, or augmented reality. In general, they are used in applications where the relative distance between the camera and the subject is required.

A typical and arguably the most common marker is the QR code. It can store up to 4,296 characters and includes a Reed-Solomon error correction algorithm that allows for decoding even partially overlapped QR codes. In addition, it is open source and well documented, but its decoding cannot be achieved in real time, which makes it unsuitable for our purposes.

The characteristics that the selected marker must have, due to the drone's movement in space and the speed at which it can still recognize the marks, are:

1. Real-time detection - To perform the automatic localization process through a visual sign, we assume the speed of every drone is the same (we do not take into account faster or slower drones), so the detection speed must be as high as possible.
2. Tolerance to changes in lighting conditions - This is required because the system will be deployed in industrial environments characterized by fluctuating lights, shadows, etc.
3. Small size - This is needed to reduce system failure. We must find the best compromise between size, detection/decoding speed, and algorithm robustness.
4. Robustness in the detection of blurred marks - This is caused by rapid movements and is related to point 1.

A similar problem has been analyzed by [7]. They had almost identical conditions when trying to find the best-suited marker type for their needs and concluded that the best option overall is AprilTag.

AprilTag [10] is a square fiducial marker developed by Edwin Olson from the University of Michigan. Marker detection with this library is tolerant to changes in lighting conditions and viewing angles, and offers real-time recognition. The team also conducted several detection/decoding tests to evaluate the performance. The results showed that AprilTag is consistent in various lighting conditions, marker sizes, and distances between the marker and the scanning camera. Given the availability of the source code, its recognition performance, and tolerance to physical conditions, AprilTag is the best pick for an indoor UAV localization marker. With this knowledge, we will use this marker in our experiments with visual recognition.

A. MarvelMind

This system is designed and constructed by the Marvmind Robotics company. It can serve as a substitute for GPS when real GPS is not available, or the signal is insufficient (which is precisely our case). The system is based on stationary transmitters that communicate with a mobile transmitter located on a drone, whose position we aim to monitor. The basic package is set up in the premises of the Faculty of Aeronautics at the Technical University of Kosice. This system operates on the free frequency of radio waves (915/868 MHz or 433MHz). Using the system involves attaching and installing a mobile transmitter on a drone. This drone device provides data in the native GPS format, replacing the real GPS data, and allowing us to process the position based on coordinates. However, the specific use depends on the drone and the software solution in use.

B. MAVLink

The MAVLink protocol is now considered one of the standards in drone control, and we aim to implement this communication when performing experimental verification using GPS to control the drone. This protocol defines the mechanism of the message structure and the way they are serialized at the application layer. These messages are then sent to the lower layers (i.e., the transport and physical layers) to be transmitted to the network. The advantage of the MAVLink protocol is its light structure, which supports various types of transport layers and media. It can be transmitted via WiFi, Ethernet (i.e., TCP/IP networks), or low bandwidth serial telemetry channels operating at frequencies below GHz, namely 433 MHz, 868 MHz, or 915 MHz [11]. Frequencies less than GHz allow us to achieve large communication ranges for the remote control of an unmanned system. The maximum data transfer rate can reach up to 250 kbps, and the maximum range is usually expected to be around 500 m. However, this heavily depends on the environment, noise level, and antenna settings.

IV. Drone used to verify designed solution

As we couldn't obtain the originally intended drone, which would potentially be used in the real world if this solution for indoor UAV navigation proved successful, we needed to find an alternative for testing our designs in our experiments. The Ryze Tello by DJI company [12] appeared to be a practical replacement. This drone is used in education and serves as a lightweight introduction to the UAV world for people who are not experienced developers, and thus it was not difficult to implement a software solution. This drone can be programmatically controlled using Python. It costs about $100, is light and small (98mm*92.5mm*41mm), has an 8MP camera, and can shoot video at a resolution of 1280 × 720 with 30 frames per second. Unfortunately, it does not have GPS, so we were not able to test the solution using the Marvelmind system 4. The program connection is facilitated by a WiFi network transmitted by the drone. From a computer (or alternatively, a mobile phone), we simply connect to the network. After successfully connecting to the given WiFi network, we are ready to run our software solutions on the corresponding drone.

As a payload that represented the transported load in the real world, we used a safety reflective strip measuring 3 x 3 x 3 centimeters and weighing 10 grams. We chose it because of its low weight; an object with a higher weight would not add value to our needs and therefore, using a heavier object wouldn't achieve anything. Another reason is that we wouldn't be able to transport a heavier object with the aforementioned drone. If we tried, it could disrupt the drone's balance and flight capabilities and risk causing damage or injury to nearby people.

V. Methods

To demonstrate usability and provide a proof of concept, we designed an experiment in which the drone navigates in unknown territory with the help of markers. To view the area below it, we attached a small mirror in front of the camera, enabling us to scan and recognize markers. Initially, the drone is positioned at the starting point, denoted as 'Start/Finish' in experiment scheme 2, pointing in the direction of the arrow towards the next stop in the experiment, which is point A. From there, the drone takes off. We then activate the camera feed to observe what image our algorithm will simultaneously scan and evaluate. As in the previous example, this will be displayed on our computer.

The vertex of our test square symbolizes the location where the drone would land, or merely verify or correct its direction and position before moving further if this marker doesn't symbolize the final stop. After successfully recognizing the marker at point A, the drone repeats the process of moving away from the marker (or start point) and recognizing the subsequent marker three more times until it reaches the endpoint, marked as 'Start/Finish' on the diagram. This movement outlines a specific route we have defined for the drone, representing a path that the drone would follow under real conditions.

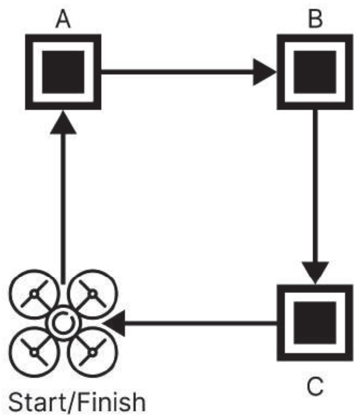

Fig. 1 Experiment pathway visualization

VI. Conclusion

With the mentioned experiment, we demonstrated the functionality and usability of the marker version. The drone successfully navigated the designed route in unknown territory with the help of AprilTag, a type of fiducial marker. With slight modifications to the drone, we were able to follow the designed route by moving over the markers, scanning them, recognizing them, and then moving on to the next marker.

As for future steps, we would definitely recommend using a drone that supports GPS signal and verifying the corresponding version of the experiment. This method of navigating unknown areas is more robust and less restrictive than using markers. When using markers, we need to first have them, then choose the best suitable spots for installation, and calculate distances and angles between them. By using a GPS signal (whether real or substituted), none of these steps are necessary.

Acknowledgment

This publication was realized with support of the Operational Programme Integrated Infrastructure in frame of the project: Intelligent systems for UAV real-time operation and data processing, code ITMS2014+: 313011V422 and co-financed by the European Regional Development Fund.

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